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Science | Sciences
Gulf Region
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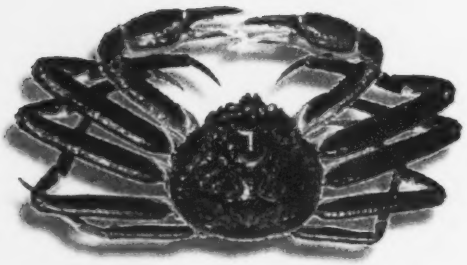
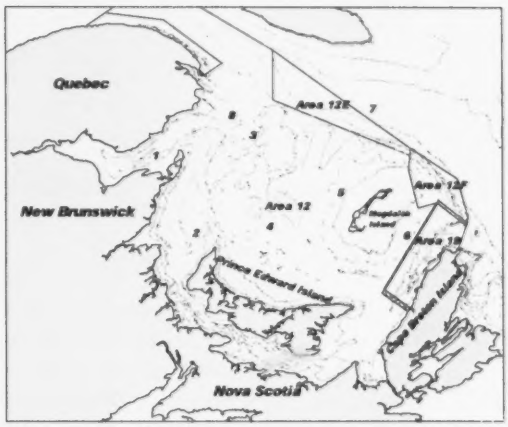
Science Advisory Report 2011/002

ASSESSMENT OF SNOW CRAB IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 19, 12E AND 12F)





1. Chaleur Bay
2. Shediac Valley
3. Orphan Bank
4. Bradelle Bank
5. Magdalen Channel
6. Cape Breton Corridor
7. Laurentian Channel
8. American Bank

Figure 1: Map of the southern Gulf of St. Lawrence showing the management areas, fishing grounds and management buffer zones (shaded area).

Context

Snow crab, Chionoecetes opilio, has been commercially exploited in the southern Gulf of St. Lawrence since the mid 1960s. There are four individually managed fishing areas among which Area 12 (Figure 1) is the largest fishery in terms of its fishable surface, number of participants and landings. In Areas 12, 12E and 12F, the fishing season generally starts in April-May as soon as the Gulf is clear of ice and continues into early summer while in Area 19, the fishery opens after June 30 and usually ends in mid-September. The landing of females is prohibited and only hard-shelled males ≥ 95 mm of carapace width are commercially exploited.

This fishery grew quickly from 1966, peaking at 33,400 t in 1982 and dropped to the lowest catch of 8,900 t in 1990. Landings have fluctuated since with peaks in 1995 of 22,750 t and in 2005 of 36,200 t. Landings were 9,549 t in 2010.

DFO Gulf Region Ecosystem and Fisheries Management requested an assessment of the resource status in 2010 and catch advice for the 2011 fishery. This document provides an overview of the assessment results and the science advice. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 19, 12E and 12F) is based on fishery independent trawl surveys to develop indicators of : abundance (commercial biomass), reproductive potential (numerical abundance of mature females), recruitment, and to estimate exploitation rates in the fishery. A science peer review meeting was conducted Feb. 9-10, 2011 in Moncton, NB. Participants (53 in total) at the science review included DFO Oceans and Science, DFO Ecosystem and Fisheries Management, the fishing industry, provincial governments and First Nations communities.

Canada

SUMMARY

- Snow crab in management Areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.
- The landings of snow crab from the southern Gulf of St. Lawrence in 2010 were 9,549 tons from a quota of 9,547 t.
- The exploitation rate in the southern Gulf of St. Lawrence in 2010 was 36.6%.
- The 2010 survey biomass of commercial-sized adult crabs was estimated at 30,500 t (27,400 to 33,700 t), an increase of 17% from 2009. The 2010 biomass level is within the caution zone of the Precautionary Approach framework but close to the upper stock reference point of 34,000 t.
- The residual biomass (13,500 t) from the 2010 survey increased by 26% compared to 2009.
- Fifty six percent (56%) of the 2010 survey biomass, available for the 2011 fishery, is composed of new recruitment (17,000 t). The recruitment to the fishery in 2010 increased (10%) relative to 2009.
- An increasing trend in recruitment of commercial-sized adult male crab to the fishery is anticipated into the 2015 fishery.
- The abundance of mature females increased in 2010 relative to the low values during 2005 to 2009.
- A risk analysis of catch options relative to reference points for the 2011 fishery is provided.

Fishery performance in 2010 by management area

Area 12:

- The 2010 landings in Area 12 were 7,719 t (quota of 7,700 t).
- The CPUE was comparable to 2009 but decreased from 2007.
- The incidence of soft-shelled crab remained low at 6.5%, but locally, Chaleur Bay and nine additional grids were closed during the fishing season.

Area 19:

- The 2010 landings in Area 19 were 1,360 t (quota of 1,360 t).
- The CPUE in 2010 increased compared to 2009 and represents the highest observed since records began in 1987.
- The incidence of white-crab decreased from 13.2% in 2009 to 7.7% in 2010 and four of the nine sectors within Area 19 were closed during the fishing season.

Area 12E:

- In Area 12E, the landings were 50 t, 74.6% of the 67 t quota.
- The CPUE in 2010 increased compared to 2009 but remained low.
- The incidence of soft-shelled crab in 2010 increased to 14.7% compared to 7.8% in 2009. No grids were closed during the fishing season.

Area 12F:

- The 2010 landings in Area 12F were 420 t (quota of 420 t).
- The CPUE in 2010 increased compared to 2009 but is among the lowest values since the beginning of the fishery in 1995.
- The incidence of soft-shelled crab decreased from 11.4% in 2009 to 8.6% in 2010. Two of the three sectors within Area 12F were closed during the fishing season.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*) is a crustacean like lobster and shrimp, with a flat, almost circular, body and five pairs of spider-like legs. The hard outer shell is periodically shed in a process called moulting. After moulting, crabs have a soft shell for a period of 8 to 10 months. Soft-shelled crab is defined by shell hardness (<68 durometer units) and includes both new-soft (condition 1) and clean hard-shelled crab (condition 2). The term white-crab is used in the summer fishery of Area 19 because the newly-molted crabs have reached a relatively harder carapace than those observed during the spring fishery (Areas 12, 12E and 12F). White crab is defined by shell hardness (<78 durometer units) and includes both new soft (condition 1) and clean hard-shelled crab (condition 2).

Unlike lobsters, snow crabs do not continue to moult throughout their lives. Females stop growing when they acquire a wide abdomen for carrying eggs, which occurs at carapace widths (CW) less than 95mm. Males stop growing when they acquire large claws on the first pair of legs, which can occur at CWs between 40 and 150 mm. Females produce eggs that are carried beneath the abdomen for approximately 2 years. The eggs hatch in late spring or early summer and the newly-hatched crab larvae spend 12-15 weeks floating freely in the water column. At the end of this period, they settle on the bottom. It takes at least 8-9 years (post-settlement) for males to reach legal size.

Fishery

Until 1994, the snow crab fishery in Area 12 (Figure 1) was exploited by 130 mid-shore fish harvesters from New Brunswick, Québec and Nova Scotia. Since 1997, the PEI coastal fishery, (formerly Areas 25/26) has been integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly Area 18) was also integrated into Area 12. For the purpose of this assessment, Area 12 refers to the new management unit (Figure 1). The number of licenses in Area 12 was 261 in 2010.

In 1978, Area 19 (Figure 1) was established for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 m (45 feet) in length. There were 162 licenses in Area 19 in 2010.

Areas 12E and 12F were introduced in 1995 as exploratory fisheries. In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial fishing areas. There are 8 and 18 fish harvesters from New Brunswick, Nova Scotia, PEI and Québec in Areas 12E and 12F, respectively.

The minimum legal carapace width is 95 mm, females are not harvested and soft-shell and white crab is not targeted by the fishery. Baited traps, constructed of wire or tubular steel, are used to catch crab, mainly on mud or sand-mud bottoms at temperatures ranging from -1 to 4.5°C, and depths ranging from 50 to 280 m. The fishery takes place from spring to early summer in Areas 12, 12E and 12F and after June 30 in Area 19.

Management of these fisheries is based on quotas and effort controls (number of licenses, trap allocations, trap dimensions, and seasons). There are soft-shelled and white crab protocols which allow for closure of portions of each fishing area when the proportion of the catch

comprised of these exceeds 20%. The protocols are in place to maximize the yield and the reproductive potential of the resource.

Table 1. Number of licenses, boats, traps, quota and opening and closing dates in snow crab fishery by management area in the southern Gulf of St. Lawrence in 2010.

	Area				
	12	12E	12F	19	Southern Gulf
Number of licenses	261	8	18	162	449
Number of boats	288	3	17	99	424
Total traps	32,390	800	1,350	1,699	36,639
Opening date	April 21	May 05	April 12	July 14	
Closing date	July 18	July 18	July 17	July 30	
Quota (t)	7,700	67	420	1,360	9,547
Landings (t)	7,719	50	420	1,360	9,549

The landings from the southern Gulf of St. Lawrence increased from 1969 to the present with three periods of high landings: 1981-1986, 1994-1995, and more recently 2002 to 2009 (Figure 2). The peak landing was reported in 2005 (36,118 t) while the lowest landing was reported in 1975 (4,632 t).

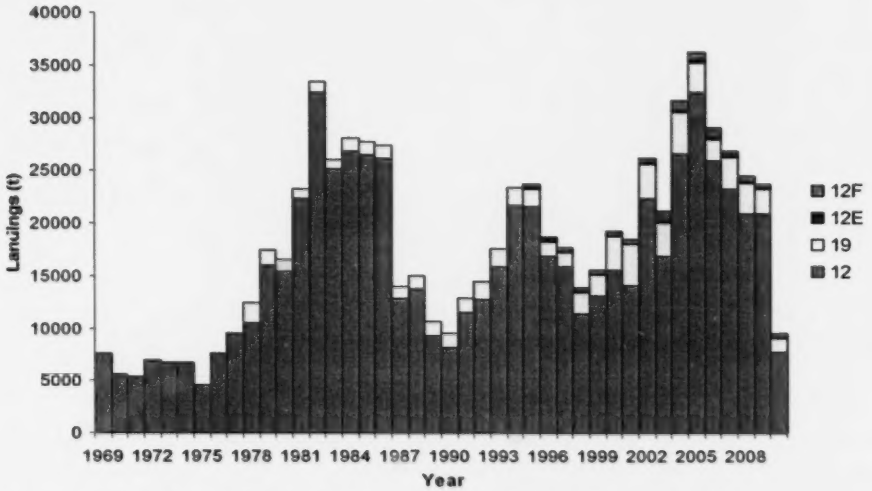


Figure 2: Landings in the southern Gulf of St. Lawrence snow crab fishery.

The 2010 fishing season in Area 12 opened on April 21 and closed on July 18 with reported landings of 7,719 t (quota of 7,700 t) (Tables 1, 2; Figure 2). In accordance with the soft-shelled crab protocol, Chaleur Bay (65 grids) and 9 additional grids were closed during the 2010 fishing season. The fishing effort estimated from logbooks varied from 337,960 to 544,454 trap-hauls during 2002 to 2009 and decreased to 161,148 trap hauls in 2010 (Table 2).

Table 2. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	22,000	17,148	26,600	32,336	25,869	23,207	20,900	20,900	7,700
Landings (t)	21,869	16,898	26,626	32,363	25,889	23,243	20,911	20,896	7,719
CPUE (kg/trap-haul)	40.2	50.0	54.9	63.7	64.4	65.7	56.4	48.2	47.9
Effort (trap hauls)	544,454	337,960	484,991	508,053	402,702	353,775	370,762	433,527	161,148
Soft-shelled crab (%) in catches	4.6	3.3	3.0	3.9	3.1	2.0	3.0	5.0	6.5
Grids closed (total of 323)	100	0[1]	17	68	11	5	3	78	74

[1] In 2003, the area was divided into four sectors and none of the sectors were closed.

The 2010 fishing season in Area 19 opened on July 14 and ended on July 30 with reported landings of 1,360 t (quota of 1,360 t) (Tables 1, 3; Figure 2). In accordance with the white crab protocol, four of the nine sectors within Area 19 were closed during the 2010 fishing season due to high incidence of white crabs in the catches. The fishing effort in Area 19 decreased from 33,193 trap hauls in 2009 to 11,138 trap hauls in 2010.

Table 3. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 19.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	3,285	3,106	5,092	2,878	2,000	3,074	3,002	2,433	1,360
Landings (t)	3,279	3,103	3,894	2,827	1,989	3,034	2,929	2,370	1,360
CPUE (kg/trap-haul)	72.3	103.6	68.9	68.1	84.4	71.3	76.3	71.4	122.1
Effort (trap hauls)	43,662	29,952	56,517	41,512	23,566	42,553	38,388	33,193	11,138
White crab (%) in catches	3.5	3.7	7.1	9.8	8.3	8.3	10.2	13.2	7.7
Sectors closed[1]	0/4	0/4	4/4	0/4	2/4	0/4	4/4	9/9	4/9

[1] Total number of sectors was changed from 4 to 9 sectors in 2009.

The fishing season in Area 12E began on May 5 and ended July 18 with reported landings of 50 t, 74.6% of the 67 t quota (Tables 1, 4; Figure 2). The fishing effort in Area 12E decreased from 4,653 trap hauls in 2009 to 1,825 trap hauls in 2010. In accordance with the soft-shelled protocol, no grids within Area 12E were closed during the 2010 fishing season.

Table 4. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12E.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	163	350	350	450	550	221	400	200	67
Landings (t)	165	345	349	449	411	220	187	67	50
CPUE (kg/trap-haul)	56.6	63.1	55.6	80.6	40.8	37.2	20.3	14.4	27.4
Effort (trap hauls)	2,916	5,471	6,277	5,571	10,074	5,914	9,232	4,653	1,825
Soft-shelled crab (%) in catches	0.3	1.2	1.5	2.9	7.8	1.3	10.1	7.8	14.7
Grids closed (total of 8)	0	0	0	0	2	0	0	2	0

In Area 12F, the fishery opened on April 12 and closed on July 17 with reported landings of 420 t (quota of 420 t) (Tables 1, 5; Figure 2). The fishing effort increased from 14,045 trap hauls in 2009 to 14,335 trap hauls in 2010. In accordance with the soft-shelled protocol, two of the three sectors within Area 12F were closed during the 2010 fishing season due to high incidence of soft-shelled crabs in the catch.

Table 5. Quota, landings, fishing effort and catch performance for the snow crab fishery in Area 12F.

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Quota (t)	378	808	808	480	815	408	585	465	420
Landings (t)	378	817	806	479	787	370	431	309	420
CPUE (kg/trap-haul)	85.2	78.1	74.8	93.7	55.9	30.2	27.8	22.0	29.3
Effort (trap hauls)	4,437	10,460	10,775	5,112	14,079	12,252	15,504	14,045	14,335
Soft-shelled crab (%) in catches	0.5	0.4	0.6	0.8	3.5	2.4	7.3	11.4	8.6
Sectors closed (total of 3)	0	0	0	0	0	1	3	3	2

Catch per unit of effort (CPUE) expressed as kg per trap-haul (kg/th) is calculated from logbook data as the ratio of total landings (kg) to total effort (trap-hauls). In Area 12, the annual unadjusted mean CPUE in 2010 (47.9 kg/th) was comparable to 2009 but decreased from 2007 (65.7 kg/th), (Table 2; Figure 3). In Area 19, the CPUE increased in 2010 compared to 2009 (Table 3, Figure 3). The CPUE in Areas 12E and 12F increased in 2010 (Tables 4, 5; Figure 3).

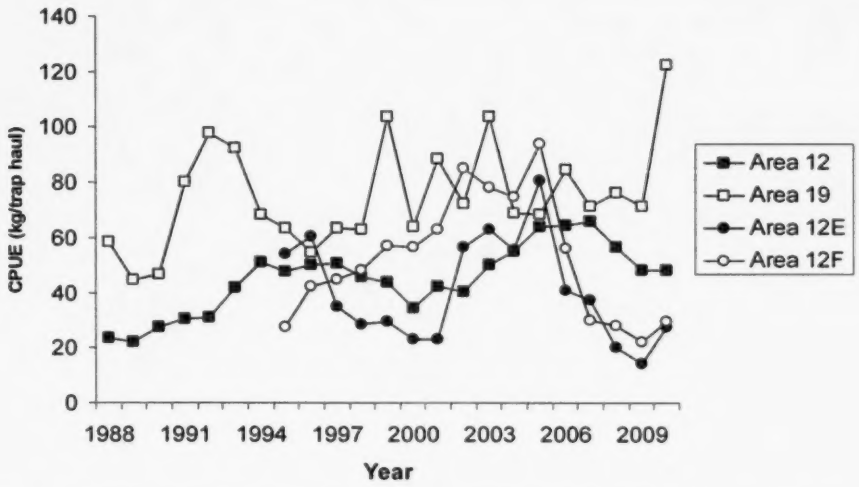


Figure 3: CPUE in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F.

The percentage of soft-shelled crabs and white crab is calculated using data collected from the at-sea observer program. The incidence of soft-shelled crab and white crab in catches is strongly influenced by the fishing strategy used by harvesters during the season, as well as crab abundance in the area.

The percentage of soft-shelled crab in Area 12 has remained low since 2002 and was at 6.5% in 2010 (Table 2). In Area 19, the percentage of white crab decreased from 13.2% in 2009 to 7.7% in 2010 (Table 3). The percentage of soft-shelled crabs in Area 12E increased from 7.8% in

2009 to 14.7% in 2010 (Table 4). In Area 12F, the percentage of soft-shelled crabs decreased from 11.4% in 2009 to 8.6% in 2010 (Table 5).

ASSESSMENT

Snow crab in management Areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

Stock Trends and Current Status in the Southern Gulf

Statements of stock status are based on inferences from abundance data from annual trawl surveys conducted during July to September, over the entire area of snow crab distribution in the southern Gulf. This provides estimates of commercial biomass which is comprised of residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males larger than 95 mm CW (R-1) that will be available to the fishery the following fishing season). It also provides estimates of future male recruitment to the fishery (prerecruits defined as R-4, R-3 and R-2). The prerecruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56-68, 69-83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. The abundances of small adolescent male and female instar VIII (34-44 mm CW) were also estimated as an indicator of long-term recruitment. It takes at least six years for an adolescent male of instar VIII to reach the commercial size of 95 mm CW.

Future and current spawning stock abundance consists of females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous females (first brood). The term 'multiparous' refers to females which are carrying a brood for the second time or more. The term 'mature females', includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of St. Lawrence from the 2010 trawl survey was estimated at 30,500 t with 95% confidence limits (CL) of 27,400 t to 33,700 t (Table 6; Figure 4). The estimated commercial biomass in the southern Gulf increased by 17% relative to 2009 (26,100 t; 95% CL 23,400 t – 29,000 t). The 2010 commercial biomass in Areas 12, 19, 12E and 12F correspond to 80.41%, 15.95%, 0.70% and 2.94%, respectively of the southern Gulf biomass point estimate of 30,500 t.

The residual (carapace conditions 3 to 5) biomass of commercial sized male crab after the 2010 fishery was 13,500 t (95% CL 11,600 t – 15,700 t), an increase of 26% compared to 2009 (Table 6; Figure 5). The recruitment to the fishery at the time of the survey was 17,000 t (95% CL 14,900 t – 19,200 t) comprising 56% of the commercial biomass (Table 6; Figure 5). The recruitment to the fishery in 2010 increased by 10% relative to the 2009 estimate.

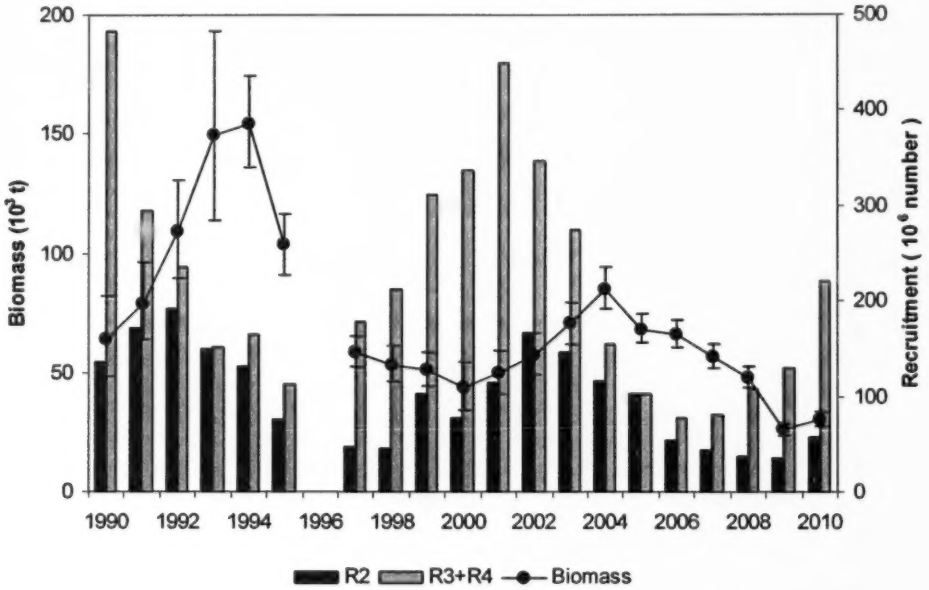


Figure 4: Survey biomass of commercial-sized adult males (t; mean and 95% confidence intervals) and abundance (in millions of crabs) of future recruitment in the southern Gulf of St. Lawrence.

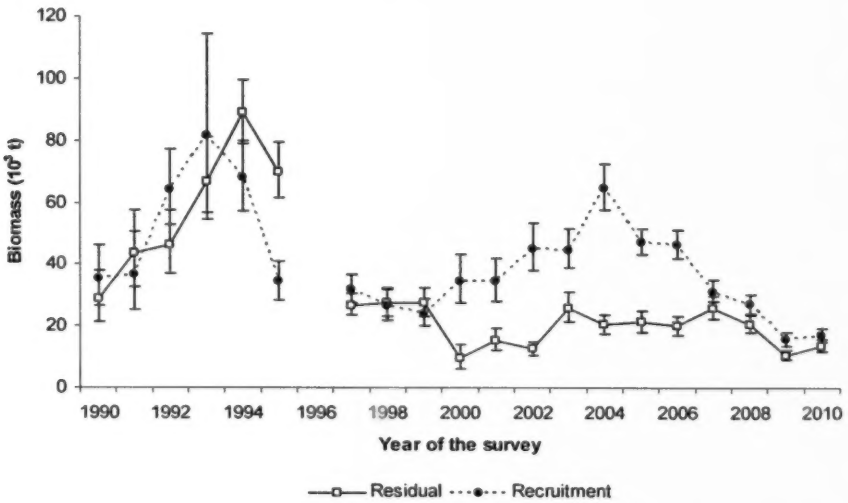


Figure 5: Recruitment and residual biomass (t; mean and 95% confidence intervals) in the southern Gulf of St. Lawrence, 1990 to 2010.

In the 2010 trawl survey, concentrations of commercial-sized adult males were located in Chaleur Bay, American Bank, Bradelle Bank, Shediac Valley, southern part of the Magdalen Channel and west of Cape Breton Island (Figure 6). The spatial distributions of commercial-sized adult males has varied annually during increasing and decreasing phases of the commercial biomass (Figure 7).

Table 6. Total commercial, recruitment, and residual biomass (t; mean with 95 % confidence intervals) of commercial-sized adult males in the southern Gulf of St. Lawrence.

Year	Commercial Biomass (t)	Recruitment Biomass (t)	Residual Biomass (t)
1990	**63,900** 48,700-82,300	**35,400** 26,500-46,300	**28,900** 21,600-37,900
1991	**78,900** 63,900-96,400	**36,500** 25,500-50,700	**43,800** 32,700-57,400
1992	**108,800** 89,800-130,600	**64,000** 52,700-77,100	**46,500** 37,100-57,400
1993	**149,700** 114,000-193,000	**81,700** 56,600-114,200	**66,800** 54,500-81,100
1994	**154,300** 136,000-174,300	**67,900** 57,400-79,700	**88,800** 79,200-99,400
1995	**103,420** 91,200-116,800	**34,300** 28,300-41,200	**69,900** 61,400-79,200
1996	**N/A**	**N/A**	**N/A**
1997	**58,600** 52,500-65,200	**32,000** 27,700-36,700	**26,800** 23,300-30,500
1998	**53,500** 46,200-61,600	**26,600** 21,900-31,900	**27,300** 23,000-32,200
1999	**51,100** 44,300-58,600	**24,000** 20,000-28,700	**27,400** 22,900-32,500
2000	**43,800** 34,600-54,700	**34,700** 27,400-43,200	**9,400** 6,100-13,900
2001	**49,600** 41,300-59,100	**34,400** 27,900-41,800	**15,500** 12,300-19,200
2002	**57,600** 49,300-66,800	**45,100** 37,900-53,200	**12,500** 10,300-15,000
2003	**70,400** 61,900-79,600	**44,600** 38,600-51,300	**25,900** 21,400-31,100
2004	**84,900** 76,500-94,000	**64,600** 57,400-72,500	**20,400** 17,500-23,600
2005	**68,200** 62,300-74,400	**47,200** 43,200-51,400	**21,300** 18,100-24,800
2006	**66,000** 60,400-72,100	**46,300** 41,900-51,000	**19,900** 17,100-23,100
2007	**56,800** 52,100-61,800	**31,100** 27,800-34,700	**25,900** 22,200-29,900
2008	**48,000** 43,800-52,400	**27,100** 24,100-30,300	**20,700** 17,900-23,800
2009	**26,100** 23,400-29,000	**15,500** 13,300-17,900	**10,700** 9,200-12,300
2010	**30,500** 27,400-33,700	**17,000** 14,900-19,200	**13,500** 11,600-15,700

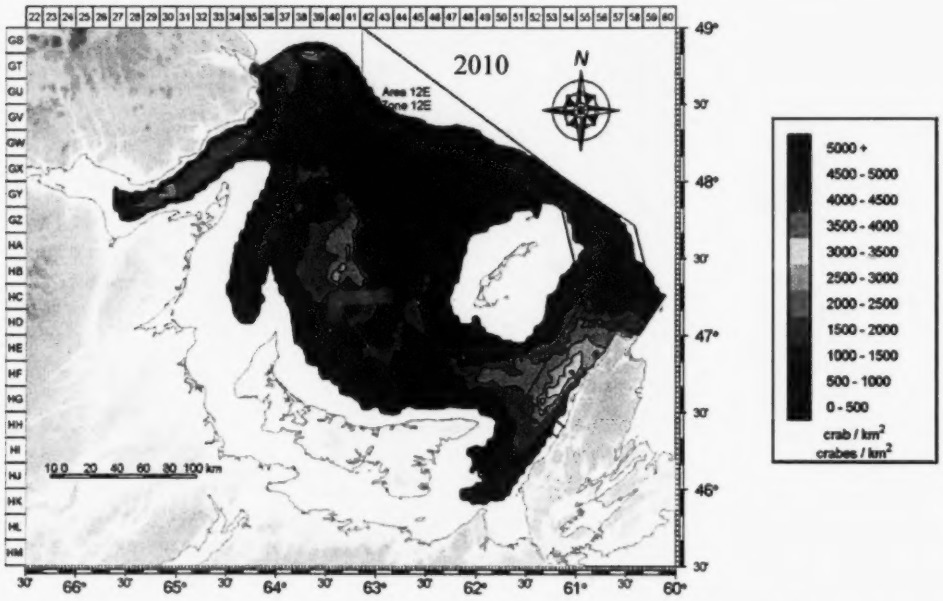


Figure 6: Density (number per km²) contours of adult male crab ≥95 mm CW in the southern Gulf of St. Lawrence in 2010.

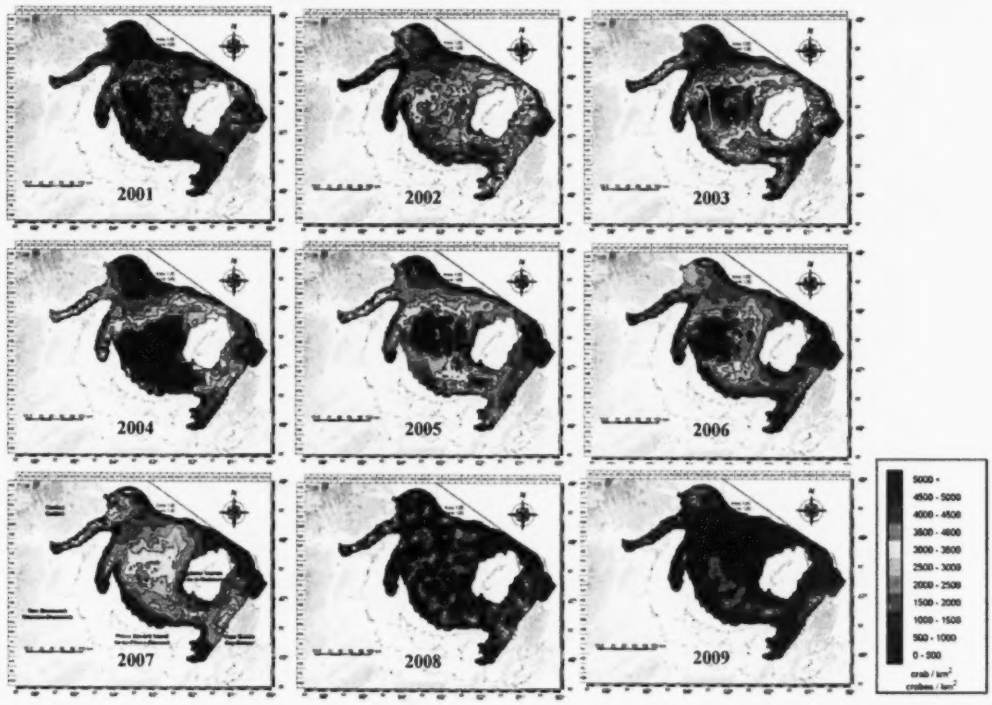


Figure 7: Density (number per km²) contours of adult male crab ≥95 mm CW in the southern Gulf of St. Lawrence, 2001 to 2009.

The commercial biomass estimate from the fall survey of 2009 was 11% higher than the sum of the residual biomass from the fall survey in 2010 and the landings in 2010. In previous years, the average difference over the time series has been 29%. This difference (termed non-fishing directed mortality) could be attributed to a number of factors including variability in survey estimates, natural mortality, fishery induced mortalities, as well as emigration out of the sampled area. The total mortality, expressed as a proportion, was estimated at 48% in 2010 and varied between 35% and 88% since 1991 (Figure 8).

The exploitation rate in the southern Gulf of St. Lawrence in 2010, which is the ratio between the catch of the 2010 fishery and the commercial biomass estimated from the 2009 trawl survey, was 36.6%. Exploitation rates have been relatively stable since 2000 at a level of about 40% (Figure 8).

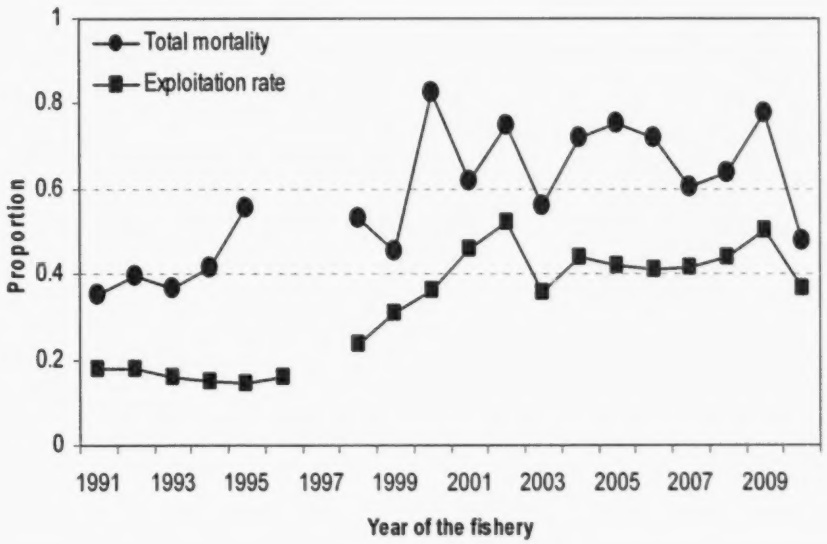


Figure 8: Exploitation rates by the fishery and total mortality of commercial-sized adult male snow crab in the southern Gulf of St. Lawrence, 1991 to 2010.

An increasing trend in recruitment of commercial-sized adult male crab to the fishery is anticipated until the 2015 fishery based on the 2010 survey abundances of adolescent males of R-2, R-3 and R-4 (Figures 4, 9, 11). The abundances of male and female Instar VIII (34-44 mm CW) observed in the trawl survey in 2010 are comparable to 2009 (Figure 10). The abundance of Instar VIII observed from 2006 to 2009 is 42% lower than the peak observed in the previous recruitment wave from 1996 to 1999 (Figures 10, 11).

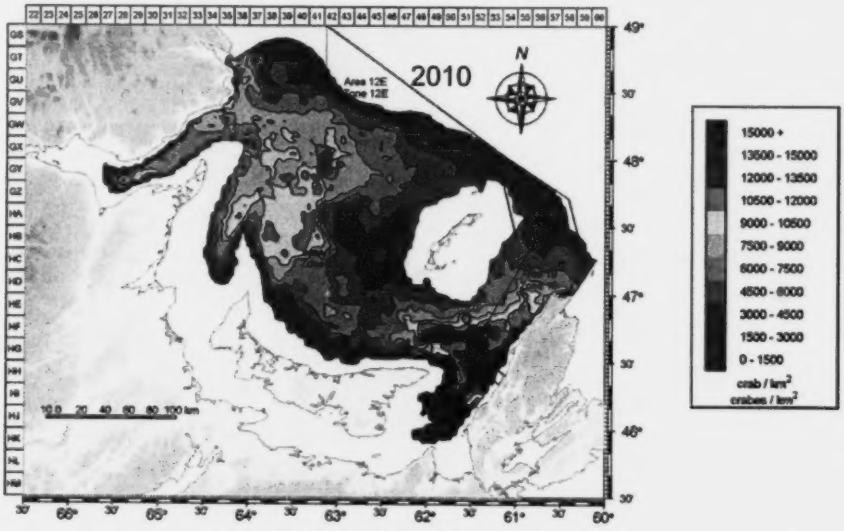


Figure 9: Density (number per km^2) contours of adolescent male crab ≥ 56 mm CW in the southern Gulf of St. Lawrence in 2010.

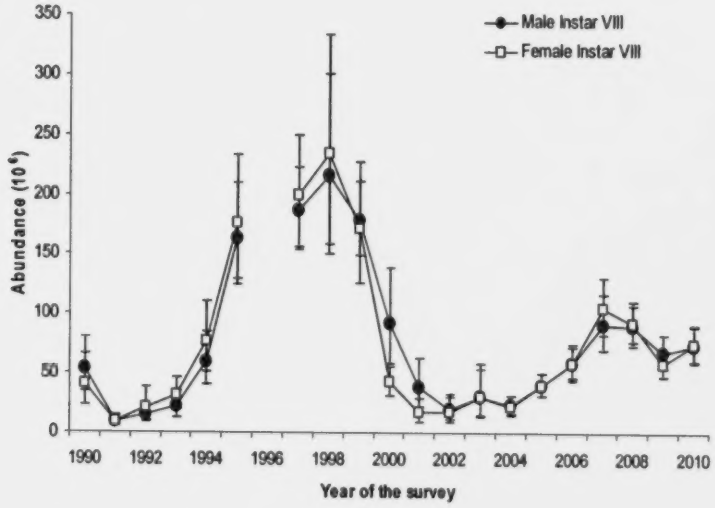


Figure 10: Abundance of males and females Instar VIII, 34 – 44 mm CW, (number of individuals, mean with 95% confidence intervals) based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 1990 to 2010.

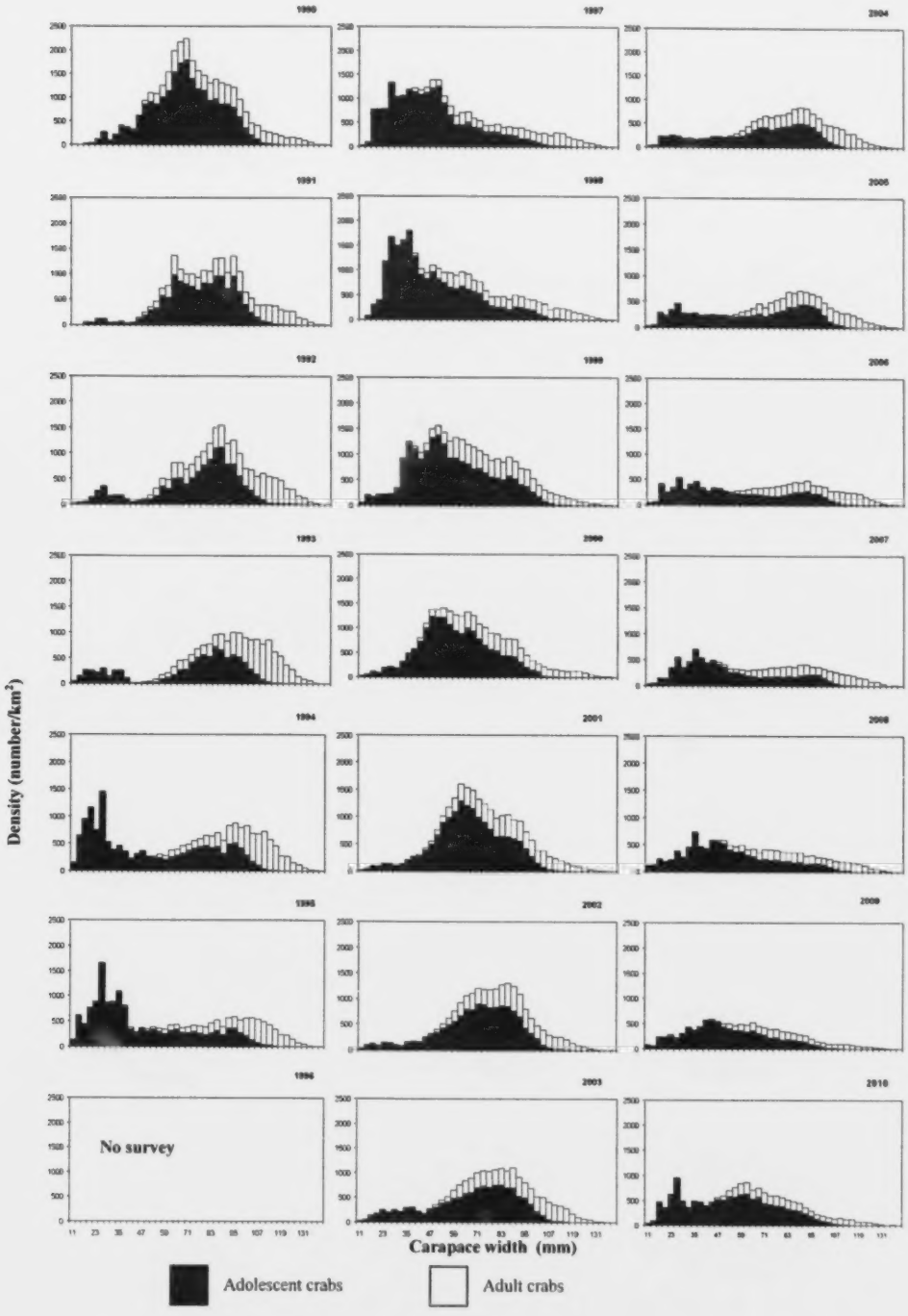


Figure 11: Size frequency distributions (by 3 mm interval) of male crab sampled during the trawl survey in the southern Gulf of St. Lawrence after the fishing season. These size frequency distributions represent the mean number of male crab per km² based on samples in the trawl survey and are not adjusted with geostatistical analysis (kriging) for total biomass.

Reproduction

The abundance of mature females increased in 2010 relative to the low values observed during 2005 to 2009 (Figure 12). The continued low abundance of immature and pubescent females in the population in recent years suggests that the abundance of mature females will remain low in the coming years (Figure 12).

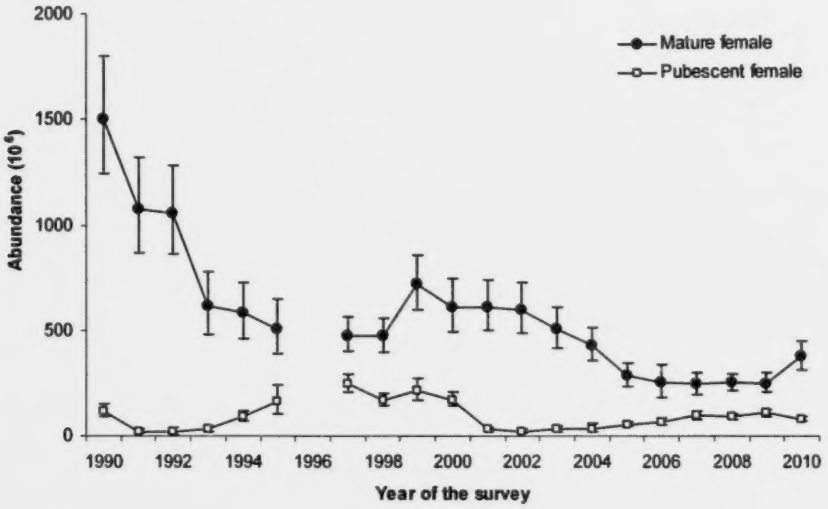


Figure 12: Annual female abundances (number of individuals; mean with 95% confidence intervals) based on the trawl surveys in the southern Gulf of St. Lawrence, 1990 to 2010.

Sources of Uncertainty

The trawl survey data were processed using the procedure defined in the Assessment Framework Workshop (DFO 2006). A review of the standardization for the tow length, trawl opening width and area of polygon for the time series 1988 to 2006 was reviewed at the 2008 meeting (Moriyasu et al. 2008). Nevertheless, other factors such as the change in vessel cannot be addressed without a comparative survey. It was assumed that the trawl survey biomass estimates for commercial size males are absolute measures of abundance.

An independent analysis by an industry consultant proposed that it is impossible to reconstitute the biomass estimates of the previous years to compensate for the lack of samples in some sectors in the southern Gulf survey coverage area whatever the kriging method used. This individual conclusion needs further review. A new review of the approaches currently used to reconstruct the time series, to assess the level of bias, and to consider alternate approaches to reconstitute useable estimates in order to conserve the historical series should be considered.

Other uncertainties such as estimation uncertainty, growth, natural mortality (including predation) and movement make it difficult to reliably predict the commercial biomass more than one year in advance.

In 2010, soft-shelled and white adult commercial-sized crab comprised an estimated 10.5% (by numbers) of the landed catch in the southern Gulf of St. Lawrence. This estimate, obtained from sea sampling of retained catch, does not concord with the observations and experience of some

participants from industry on the extent of white crab in the landings. The discordance could be due to differences in the characteristics used to define soft-shelled and white crab by science compared to the fishing industry, to localized differences in the composition of the catches, to sampling coverage, among other factors. This discrepancy needs further review.

Environmental conditions, primarily temperature, in the southern Gulf vary annually. In recent years, the temperatures have been above normal and the index of suitable habitat for crab has declined. These changes in temperature can affect a number of life history processes including moulting and growth, reproduction, larval development and the impacts of warming conditions on the snow crab life history are not well known.

CONCLUSIONS AND ADVICE

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an Upper Stock Reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. A Removal Rate Limit Reference Point (F_{lim}) defines the maximum removal rate in the healthy zone. The upper stock reference point (B_{USR}) is 34,000 t of commercial-sized adult males of all carapace conditions as estimated from the trawl survey (DFO 2010). These crabs become hard shelled commercial-sized adult males as of January of the year following the trawl survey. The biomass limit reference point (B_{lim}) value is 9,400 t (DFO 2010). The biomass limit reference point was chosen as the lowest biomass of hard shelled commercial-sized adult males which produced good recruitment rates of Instar VIII (DFO 2010). The removal reference point (F_{lim}) has been set at 40.1%, which is the annual traditional exploitation rate calculated as catch (weight) in year *t+1* divided by the estimated biomass of commercial-sized adult male crab from the post-fishery trawl survey in year *t* (DFO 2010). The southern Gulf of St Lawrence commercial biomass estimate should be used for evaluating catch options relative to the defined reference points.

Recruitment of commercial-sized adult male crab to the fishery increased in 2010. An increasing trend is anticipated until the 2015 fishery based on the 2010 survey abundances of adolescent males of R-2, R-3 and R-4.

The trajectory of stock abundance (biomass of commercial-sized adult male crab from the fall trawl survey in year t – 1) versus exploitation rate on this biomass in the fishery of year t is shown in Figure 13. The commercial biomass has varied between 26,100 t and 84,900 t during 1998 to 2010. Over this same period, exploitation rates have varied between 24% and 52%, and produced harvests of 9,549 t to 36,100 t. The estimated biomass from the 2010 fall survey, which would be available to the fishery in 2011, was 30,500 t (95% CL range 27,400 t – 33,700 t). The 2010 biomass estimate is in the cautious zone of the PA framework. When the stock is in the cautious zone, the exploitation regime should be defined at a level to favour stock increase toward and above B_{USR}.

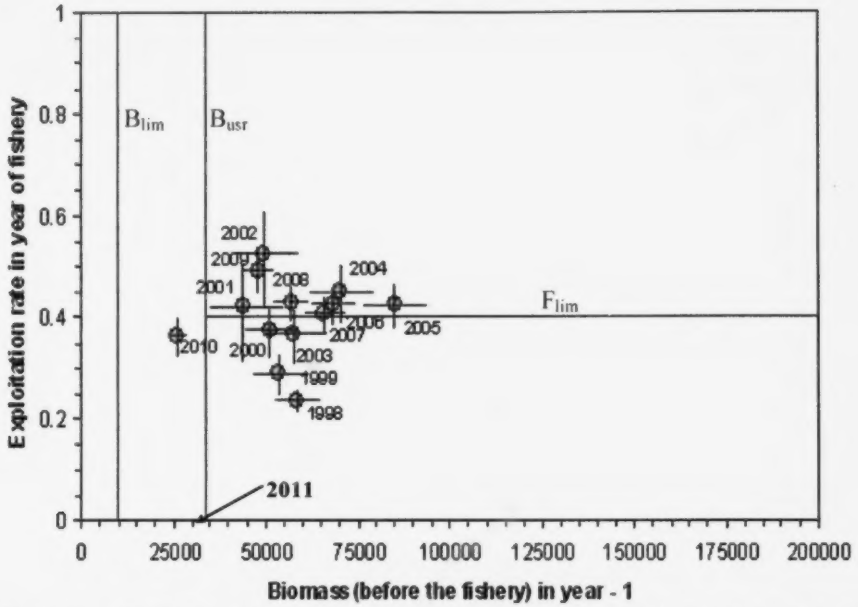


Figure 13: Trajectory of stock abundance (biomass of commercial-sized male crab as estimated from the trawl survey in year t – 1) versus exploitation rate of this biomass in the fishery of year t. Year of the fishery is labeled on the figure. Error bars are 95% confidence interval ranges.

A risk analysis was developed relative to various catch options in 2011 (Table 7; Figures 14 and 15). The choice of the catch option and its associated risk levels (probability of the event happening) are decisions to be made by management and stakeholders.

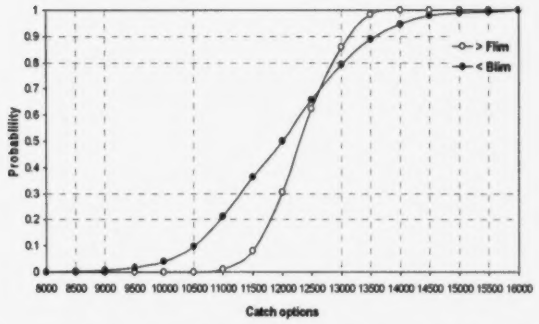


Figure 14: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim} and of the hard-shell commercial-sized adult male biomass in 2011 falling below B_{lim} for different catch options in 2011.

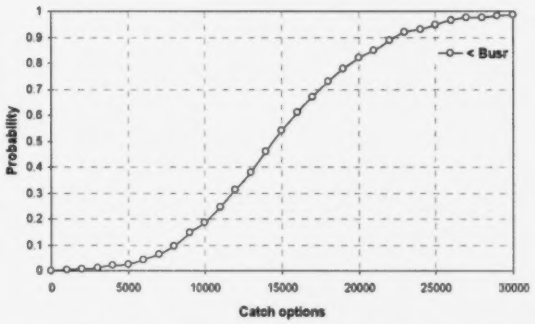


Figure 15: Risk analysis for the southern Gulf of St. Lawrence snow crab fishery showing probabilities that the commercial-sized adult male biomass in 2011 will be below B_{USR} after the 2011 fishing season for different catch options in 2011.

Table 7. Risk analysis for different catch options in 2011 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim}, of the hard-shell commercial-sized adult male biomass falling below B_{lim}, and of the total commercial-sized adult male biomass being below B_{USR} post-fishery in 2011.

	Probability		
Catch option (t)	> F_{lim}	< B_{lim}	< B_{usr}
8,000	0	0.001	0.095
8,500	0	0.002	0.117
9,000	0	0.006	0.146
9,500	0	0.016	0.170
10,000	0	0.041	0.187
10,500	0.001	0.097	0.219
11,000	0.009	0.213	0.245
11,500	0.080	0.361	0.279
12,000	0.304	0.500	0.311
12,500	0.624	0.657	0.340
13,000	0.860	0.791	0.379
13,500	0.982	0.889	0.419
14,000	0.999	0.945	0.459
14,500	1	0.980	0.497
15,000	1	0.991	0.542
15,500	1	0.994	0.576
16,000	1	0.999	0.611

OTHER CONSIDERATIONS

Ecosystem Considerations

Environmental factors, such as water temperature, can affect moulting, reproductive dynamics and the movement of snow crab. Bottom temperatures over most of the southern Gulf of St. Lawrence are typically between -1 and 3 °C, a temperature range suitable for snow crab habitat. Data collected during research surveys indicate that the bottom temperatures in deeper waters of Areas 12E and 12F are higher (1 to 5 °C) than on the crab grounds (-1 to 2 °C) in Area 12. Bottom temperatures in Area 19 are usually 1 to 2 °C warmer than on the traditional crab grounds in Area 12.

In 2010, near bottom temperatures over most of Area 12 and around Prince Edward Island were close to or above normal while Areas 19 and 12F showed significantly above normal conditions. The western part of Area 12 cooled down compared to 2009 while Areas 19 and 12F warmed up slightly during the year. Compared to normal conditions, the warmer bottom waters of 2010 are consistent with a below normal Southern Gulf snow crab habitat index (bottom area with temperature from –1 to 3 °C). The habitat index increased slightly (7%) in 2010 from 2009 to reach 50,177 km^2, but it was 3% below the 1970-2000 average of 51,970 km^2 (Figure 16). However, the mean temperature index within the habitat area in 2010 (1.3°C) increased compared to 2009 (0.9°C) by about 0.4°C (Figure 16). The 2010 mean temperature index was the second highest of the 40 year data series with the previously warmer value in 1982. The 2010 value is significantly higher than the long term mean of the index and is above the 1999-2002 and 2005-2007 warm periods. The temperature conditions are not considered to be optimal for snow crab as the area index is below normal and the mean temperature index is higher than normal.

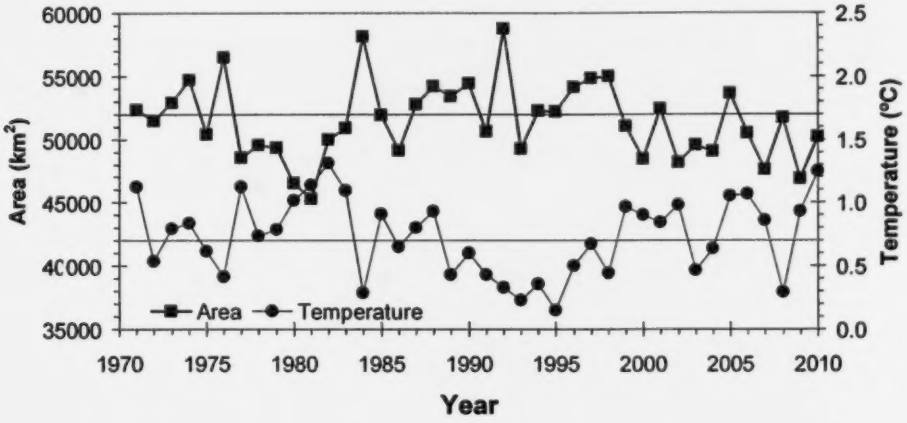


Figure 16: Snow crab habitat area index and mean temperature index in the southern Gulf of St. Lawrence.

SOURCES OF INFORMATION

DFO. 2006. Proceedings of the Assessment Framework Workshop on the southern Gulf of St. Lawrence snow crab (Areas 12, E, F and 19), Gulf Regional Advisory Process; 11-14 October 2005. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/042.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm (2009-03-23).

DFO. 2010. Reference points consistent with the precautionary approach for snow crab in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/014.

Hébert, M., E. Wade, M. Biron, P. DeGrâce, J.-F. Landry and/et M. Moriyasu. 2010. The 2009 assessment of snow crab, *Chionoecetes opilio*, stock in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2010/091. vi + 85 p.

Moriyasu, M., E. Wade, M. Hébert, and M. Biron. 2008. Review of the survey and analytical protocols used for estimating abundance indices of southern Gulf of St. Lawrence snow crab from 1988 to 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/069.

Surette, T.J., Marcotte, D., and Wade, E. 2007. Predicting snow crab (*Chionoecetes opilio*) abundance using kriging with external drift with depth as a covariate. Can. Tech. Rep. Fish. Aquat. Sci. 2763: vi + 33 p.

FOR MORE INFORMATION

Contact: Mikio Moriyasu
Oceans and Science Branch
Fisheries and Oceans Canada
Gulf Region
P.O. Box 5030
Moncton, N.B. E1C 9B6
Tel: (506) 851-6135
Fax: (506) 851-3062
E-Mail: Mikio.moriyasu@dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Gulf Region
Fisheries and Oceans Canada
P.O. Box 5030
Moncton, NB
E1C 9B6

Telephone: 506 851 6253
Fax: 506 851 2620
E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs

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